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(19) (CA) **CANADIAN PATENT** (12)

(54) MIXING OF PARTICULATE MATERIALS

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No. OF CLAIMS 46

This invention relates to the mixing of particulate materials. More particularly, the invention relates to the mixing of such materials when dispersed in a fluid medium, e.g. by the mixing of streams each containing such a material dispersed in a fluid medium.

It is known that if a second fluid stream is injected axially into the centre of a swirling annular first fluid stream or vortex and the swirling annular first fluid stream has sufficient swirl (angular momentum) and the axially injected second fluid stream has sufficient axial velocity, mixing of the streams will at first occur only to a limited extent. However, because of transfer of momentum from a swirling mode to an axial mode, the vortex flow of the first stream eventually decays and during such a decay interaction of the two streams occurs, accompanied by large scale turbulence or vortex break and the mixing of the streams. We have discovered that this phenomenon may be utilised to effect controlled reaction between and eventual intimate mixing of particulate materials dispersed within fluid streams.

Swirling or vortex flows have found application in the development of solid particle separators, heat transfer devices, gas separators and combustion devices, and have been used in a variety of such separators, heat exchangers and/or devices. In general, however, such uses have been directed to mixing solid particles with fluid media, or separating particles from fluid media and have not been concerned to achieve a controlled juxtaposition and interaction of separate streams of solid particles for a limited time prior to the intimate mixing thereof.

For instance, swirling gas reactors have been proposed by the U.S. Bureau of Mines. In such a reactor a mixture or suspension

of pulverized coal and steam is injected or pumped through the centre of the reactor and within a swirling flow of air in which pulverized coal is dispersed to be ignited by heat radiating from a hot reactor wall. The energy liberated by the burning coal increases the degree of swirl as a result. Radiant heat is emitted by the burning coal and gasifies the coal fed to the centre of the reactor. Such reactors necessarily operate with a large void fraction in order to give caking coals sufficient transit time in free flight in the reactor for them to pass through their sticky state, before reaching the reactor wall.

However, the large void fraction limits the coal throughput of the reactor and lowers its efficiency in operation; the large void fraction also limits the useful range of operation of the reactor. Moreover, the void fraction also does not always completely prevent sticky coal particles from reaching and becoming attached to the reactor wall, so that there is the risk of the reactor becoming plugged if rigid operating conditions are not adhered to. Furthermore, in such a reactor, the burning and burned coal has nothing to act as a shield between it and the reactor wall nor is the reactor self-cleaning in the event that some of the coal should stick to the reactor wall.

In this regard it should be understood that a caking coal or carbonaceous material is one which passes through a sticky or tacky state when subjected to temperatures of about 400°F. (205°C.) and above; when in such a state the material tends to agglomerate or cake and to attach itself to surfaces with which it comes into contact. However, the state is only temporary and disappears with the passage of sufficient time at temperatures in excess of 400°F. (205°C.). Such materials are therefore difficult to pyrolyse and current techniques for their pyrolysis usually

lowers the tar and gas yields obtainable therefrom by pre-treatment or else are not suitable for rapid pyrolysis.

Literature relevant to the present invention is as follows:

1. Benjamin, T. Brooke, Theory of Vortex Breakdown Phenomenon, Journal of Fluid Mechanics, Vol. 14, 1962.

2. Harvey, J.K., Some Observations of Vortex Breakdown Phenomenon, Journal of Fluid Mechanics, Vol. 14, 1962.

3. Friction and Forced Convection Heat-Transfer Characteristics in Tubes with Twisted Tape Generators, Journal of Heat Transfer, February 1964.

4. Hacker, D.S., Swirl Flow Reactors, University of Illinois at Chicago Circle, A.I. Ch. E. Free Forum Wednesday, December 1, 1971.

5. Murthy, S.N.B., Survey of Some Aspects of Swirling Flows, Aerospace Research Laboratories 71-0244, November, 1971.

6. Nissan, A.H. and Bresan, Swirling Flow in Cylinders, A.I. Ch. E. Journal, Vol. 7, No. 4, December, 1961.

7. Coal-To-Gas Conversion...Search for New Ideas Intensifies, Coal Age, February, 1973.

It is therefore an object of the present invention to provide a new and novel apparatus and method for mixing particulate materials, especially materials that pass through a sticky or pasty state under conditions in which the mixing is to take place.

Thus in one aspect the invention provides apparatus for mixing particulate materials, comprising: (a) a conduit reactor means having a circular cross-section; (b) a first inlet means communicating with said reactor means for admitting a primary particulate stream into said reactor means; (c) a vane means positioned in said reactor means and spaced apart from the axis of said reactor means and downstream of said first inlet means for imparting a swirling angular motion to said primary particulate stream; (d) a second inlet means communicating with said reactor means positioned for admitting a secondary particulate stream axially into said reactor means; (e) a reacting zone within

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said reactor means and downstream of said second inlet means through which said streams pass; and (f) an outlet means in said reactor means and downstream of said reacting zone for removing material from said reactor means.

The apparatus may include means for distributing a particulate material uniformly in said primary stream; a screen may conveniently constitute such distribution means.

The vane means may take various forms: for instance such means may be shaped to impart swirl to the primary stream flowing from a primary stream inlet, a vane or, preferably, an annular array of vanes being interposed in the flow path of the primary stream. One or more primary stream inlets may be arranged tangentially of and opening into the reaction zone.

Conveniently the reaction zone is annular in shape and the said swirling annulus is formed concentrically therein.

The after section may conveniently be provided with one or more swirl-stopping baffles or other means to bring about a rapid decay of the swirling annulus as this leaves the reaction zone, so as to speed intimate mixing of the two streams after they have been maintained in reacting contact, but substantially unmixed, for a prescribed reaction period in the reaction zone.

The invention also provides a process for subjecting carbonaceous particulate material to the influence of a stream comprising a heat-supplying particulate material comprising: (a) forming a primary swirling annular stream of an entrained heat-supplying primary particulate material, said primary swirling annular stream having a central cavity; (b) introducing into said central cavity a secondary stream comprising a fresh carbonaceous particulate material having an initial chemical composition; (c) subjecting said fresh carbonaceous particulate material to the influence of said heat-supplying primary particulate material thereby causing a transformation of said fresh carbonaceous particulate material into a substance of different chemical composition than said initial chemical composition, said substance comprising a solid product, and preventing free oxygen from being introduced into said reactor; and (d) removing all material from said reactor.

In yet another aspect, the invention provides a process for

pyrolyzing agglomerative carbonaceous material comprising: (a) forming a primary swirling annular stream comprising a heat-supplying particulate material in a reaction zone determined by a confining boundary, said primary swirling annular stream having a central cavity; (b) introducing into said central cavity a secondary stream comprising a particulate agglomerative carbonaceous material; (c) heating said particulate agglomerative carbonaceous material by the transfer of heat from said heat-supplying particulate material, thereby causing a transformation of said particulate agglomerative carbonaceous material into a form which will not adhere to said confining boundary, and thereby preventing particulate agglomerative material from adhering to said confining boundary, said form comprising a solid product; and (d) removing all material from said reaction zone of said reactor.

The processes and apparatus of the invention are particularly

well adapted to the gasification or like pyrolysis of carbonaceous materials such coal by reaction with hot particulate char. For such purposes the respective particulate materials may be dispersed in fluids that are inert to - i.e. not deleteriously reactive with - the particulate materials or their reaction products. Thus fluids such as nitrogen and steam may be used. The primary (char) stream may be suitably preheated before being fed to the reactor.

The invention is further explained with reference to the accompanying drawings in which:-

FIGURE 1 is an elevational view, mainly in section, of an embodiment of apparatus in accordance with the present invention;

FIGURE 2 is a sectional view of the apparatus shown in Figure 1, taken along line 2 - 2 thereof;

FIGURE 3 is an elevational view of the swirling means of the apparatus shown in Figures 1 and 2;

FIGURE 4 is a perspective view of the swirling means of Figure 3;

FIGURE 5 is an elevational view, mainly in section, of another embodiment of apparatus according to the present invention, and

FIGURE 6 is a plan view, partly in section, of yet another embodiment of apparatus according to the present invention, the arrows indicating the direction of fluid flow in the reaction zone of the apparatus.

A first embodiment of the invention is shown in Figures 1 to 4 and comprises a reactor 10 of extended upright tubular form having a first inlet 12 with an upright annular portion 14 connected to the upper end of the reactor and spanned by a

screen 16, the inlet 12 being penetrated at 18 by a tube 30 constituting a second inlet.

The reactor 10 has an annular swirling means generally designated 20 positioned in the path of incoming fluid from the first inlet 12, means 20 having a hollow core 22 extending therethrough and a convergent upright portion 24 adapted to force incoming fluid from the inlet 12 to the sides of the reactor. The portion 24 extends through the screen 16 and joins the tube 30. A lower hub portion 26 has an array of vanes 28 adapted to impart swirl to incoming fluid from the inlet 12.

The upper part of the reactor 10 immediately below the swirling means 20 constitutes a reaction zone 32 into which the second inlet comprising the tube 30 extends via the hollow core 22 of the swirling means 20, the second inlet thus being axial of the reaction zone 32.

The reactor 10 terminates in an after section 36 having a series of baffles 38.

A second embodiment of the invention is illustrated in Figure 5 and differs from that described in that its reactor generally designated 40 includes a first annular inlet 42 which is generally horizontal and tangentially connected at 44 to an annular reaction zone-constituting portion 46 of the reactor and thus forms a combined inlet and swirling means for a primary stream. The reactor 40 also has an upright second inlet 45, the annular reaction zone 46 communicating with both the first and second inlets and with an annular after section 48 having a series of baffles 50.

The third embodiment shown in Figure 6 differs from that of Figure 5 in that its reactor 52 has a multiplicity of annular

first inlets 54 tangentially connected to an annular portion thereof, whereby incoming streams are powerfully swirled.

The size of the particulate materials that may be fed to reactors embodying the invention and such as above described may vary widely, the size range and distribution in any particular case being determined by the maintenance of proper dispersion of the particles in the fluids of the respective streams. Preferably, the particle size ranges from that of dust to that of sand, a particle size of about 74 microns being most preferred with a size distribution such that at least 70% of the particles pass a 200 mesh (74 micron) screen.

In the case of the pyrolysis of carbonaceous, e.g. coal, particles by heat exchange with a primary stream of char particles, the primary stream may be preheated to any suitable temperature to carry the required heat into the reaction zone. Preheating to a temperature within the range 800 to 1900°F. (425 to 1050°C.) is suitable in most cases. The temperature of the secondary (coal) stream is generally much lower at its entry to the reaction zone.

Thus in typical use of the apparatus for coal pyrolysis, finely ground char having a particle size of about 74 microns in diameter is dispersed in an inert fluid medium or carrier gas, for instance nitrogen, and is introduced into a reactor such as shown in Figure 1 as a primary stream. The following conditions are present:

Char mass flow rate:	2600 pounds (1180kg) per hour
Carrier gas flow rate:	40 SCFM* (1133 l/m)
Gas mass flow rate:	177 pounds (80kg) per hour
Ratio of char to gas:	14.7 : 1
Temperature:	1200°F. (650°C.)

Pressure: 16 psia (1.12kg/cm^2; 1.09 ats.)

Void fraction: 0.995

Velocity: 33.9 ft/s (10.3 m/s)

Reynolds Number: 7730

Inlet, first, diameter: 3.26 in. (8.28cm)

Area for flow: 0.05796 ft^2 (53.84cm^2)

Finely-divided coal of similar particle size to the char – i.e. about 74 microns in diameter, dispersed in an inert fluid medium or carrier gas, for instance steam, is also introduced into the reactor as a secondary stream. The following operating conditions prevail.

Coal mass flow rate: 125 pounds (57kg) per hour

Carrier gas flow rate: 14 SCFM* (396 l/m)

Gas mass flow rate: 62 pounds (28kg) per hour

Ratio of coal to gas: 2 : 1

Temperature: 70°F. (21°C.)

Pressure: 16 psia (1.12kg/cm^2; 1.09 ats.)

Void fraction: 0.998

Velocity: 36.4 ft/s (11.1 m/s)

Reynolds Number: 19,000

Inlet, second, diameter: 1.049 in. (2.66cm)

Area for flow: 0.006 ft^2 (5.57cm^2)

The mixed stream resulting from mixing of the primary and secondary streams in the reactor and obtained from the after section thereof has the following characteristics:

Coal devolatilization: 40%

Molecular weight of vapors: 2[illegible]

Total char mass flow rate: 2675 pounds (1213kg) per hour

Total gas flow rate: 65.3 SCFM* (1849 l/m)

Gas mass flow rate: 289 pounds (131kg) per hour

Char to gas ratio:	9.25 : 1
Temperature:	1075°F. (580°C.)
After section diameter:	4.26 in. (10.8cm)
Area of flow:	0.09896 ft^2 (91.95 cm^2)
Void fraction:	0.997
Velocity:	29.9 ft/s (9.11 m/s)
Reynolds Number:	9500

*SCFM – Standard cubic feet per minute: measured volume corrected to represent volume at 60°F. (15.5°C.) at one atmosphere pressure.

In such an operation of the apparatus, the preheated primary (char) stream enters the reactor through the first inlet(s) and is formed into a swirling annulus against the wall of the reaction zone of the reactor. The secondary (coal) stream enters the reactor through the second inlet and is projected axially along the centre of the swirling annulus of the primary stream.

The coal in the secondary stream is heated by heat radiated from the swirling annulus of char and becomes sticky, but the swirling annulus of char prevents the sticky coal from contacting the reactor wall. The hot char also heats the fluid medium of the secondary stream by convection which in turn heats the coal in that stream, the turbulence of the secondary stream ensuring good transfer of heat from the fluid to the coal; this turbulence also results in some transfer of momentum between the char stream and the coal stream.

By the time that the streams pass into the after section of the reactor, the coal has lost its stickiness and the streams mix, the swirl-stopping baffles assisting in decay of the swirling primary stream and so assisting in bringing about rapid mixing of the two streams. The mixed streams leaving the reactor may be

separated into solid and gas products in any suitable apparatus.

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SUPPLEMENTARY DISCLOSURE

The method is useful generally in swirling flow reactors which have a primary stream containing a primary particulate material which forms a swirling annulus and a secondary stream which contains a particulate carbonaceous material injected into the central cavity of the swirling annulus with subsequent mixing of the two streams upon the decay of the swirl. Preferably the streams are maintained substantially free of free oxygen and the secondary stream is subjected to the influence of the primary stream for a period of time sufficient to cause a transformation of the particulate carbonaceous material into a substance of chemical composition different than its initial chemical composition.

In one embodiment the particulate material of the primary stream is relatively hot or heat-supplying and the particulate carbonaceous material of the secondary stream is subjected to the influence of the heat-supplying particulate material whereby a desired change occurs either physical and/or chemical in the particulate carbonaceous material of the secondary stream.

The primary stream which preferably comprises a gas which does not enter into a deleterious reaction with the particulate materials and the products produced by the process must be substantially free of free oxygen. By substantially free of free oxygen as used and claimed herein is meant that the amount of free oxygen per unit volume of particulate material admitted into the pyrolysis zone through any or all feed streams entering the pyrolysis zone is no greater than the void volume of the bulk particulate material in such unit volume. For example, the amount of free oxygen will be no greater than that which is normally included with the particulate material as it is fed from a hopper in a feed system into the pyrolysis zone in the reactor without purging the hopper to remove oxygen (or air) from the void spaces between the particles. One skilled in the art will appreciate that the amount of oxygen or air on a weight basis included in the void

spaces as described is very small and such a small amount of oxygen will not result in a significant amount of oxidation of the product.

In one embodiment the particulate material is purged with a purge gas to substantially remove the oxygen that may be present in the void space before the particulate material is fed to the pyrolysis zone.

In some applications, the primary particulate material is preheated and then conveyed in a gas stream to form the primary stream. The primary particulate materials are preferably good heat absorbers and transferers. The primary particulate material can be heated in a separate reactor either by heat exchange methods as in a heat exchanger or in a fluidized bed or transport reactor (also known as an entrained bed reactor). If the primary particulate material is carbonaceous then a fluidized bed reactor or transport reactor is particularly useful because the primary particulate material may be heated by combustion of a portion thereof in such a reactor.

The preferred primary gases are steam and/or nitrogen or mixtures thereof and the preferred primary particulate material is char from the pyrolysis of coal.

The secondary stream preferably comprises a gas. The gas should be non-deleteriously reactive with the particulate materials and the products produced by the process. The gas is preferably inert and must be substantially free of free oxygen. In some embodiments preferably the gas is steam. In many applications the particulate carbonaceous material is heated by a preheated primary particulate material which causes the particulate carbonaceous material to heat up and devolatilize thereby producing valuable gaseous, liquid and solid products.

The present process is useful for reacting two streams in a reaction zone determined by a confining boundary, by forming a primary stream comprising a first particulate material in swirling flow so as to produce a swirling annulus having a central cavity. A secondary stream comprising a second particulate material, which is carbonaceous, is introduced into the

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central cavity of the swirling annulus. Both streams are maintained substantially free of free oxygen.

The swirling annulus provides a protective shield around the reaction zone for a distance along the direction of swirling flow, the distance being sufficient to permit the second particulate material to undergo a reaction or transformation caused by the influence of said first particulate material. The reaction transforms the second particulate material into a substance of different chemical composition than its initial chemical composition. The secondary stream is then mixed with the primary stream after the desired reaction has been substantially completed. The streams may then undergo another reaction.

The present process is especially useful for pyrolyzing particulate agglomerative carbonaceous material by having the primary stream contain a heat-supplying particulate material and the secondary stream contain the particulate agglomerative carbonaceous material. The swirling annulus provides a protective shield around the reaction zone for a distance along the direction of swirling flow sufficient to permit the particulate agglomerative carbonaceous material to pyrolyze by the transfer of heat from the heat-supplying material. The particulate agglomerative carbonaceous material is thusly transformed into a solid residue which will not adhere to the confining boundary of the reaction zone. In this respect the process is especially useful for the pyrolysis of agglomerative coals.

The present process is also especially useful for an embodiment in which the primary stream comprises a gas in which the heat-supplying particulate material is entrained and the secondary stream comprises a gas in which the particulate agglomerative carbonaceous material is entrained.

The present process is still more useful and efficient when the heat-supplying particulate material is a product of the process, for example a char produced by the pyrolysis of the particulate carbonaceous material, for example coal char produced by the pyrolysis of coal.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An apparatus for mixing particulate materials comprising: (a) a conduit reactor means having a circular cross-section; (b) a first inlet means communicating with said reactor means for admitting a primary particulate stream into said reactor means; (c) a vane means positioned in said reactor means and spaced apart from the axis of said reactor means and downstream of said first inlet means for imparting a swirling annular motion to said primary particulate stream; (d) a second inlet means communicating with said reactor means positioned for admitting a secondary particulate stream axially into said reactor means; (e) a reacting zone within said reactor means and downstream of said second inlet means through which said streams pass; and (f) an outlet means in said reactor means and downstream of said reacting zone for removing material from said reactor means.

2. The apparatus of claim 1 wherein said vane means comprises a plurality of vanes.

3. The apparatus of claim 1 wherein said vane means comprises a plurality of vanes which are positioned in an annular configuration.

4. The apparatus of claim 1 further comprising a distributing means within said first inlet means for distributing particulate materials substantially uniformly in the primary stream.

5. The apparatus of claim 4 wherein said distributing means comprises a screen.

6. The apparatus of claim 1 further comprising an antiswirl-after-section means communicating with said reactor means and downstream of said reacting zone for stopping swirling motion.

7. The apparatus of claim 6 wherein said antiswirl-after-section means comprises a baffle means.

8. The apparatus of claim 6 wherein said antiswirl-after-section

means comprises a plurality of baffles.

9. The apparatus of claim 1 wherein said second inlet means terminates downstream of said vane means.

10. An apparatus for mixing particulate materials comprising: (a) a conduit reactor means having a circular cross-section; (b) a first inlet means communicating with said reactor means for admitting a primary particulate stream into said reactor means; (c) a swirling means positioned in said reactor means for imparting a swirling annular motion to said primary particulate stream; (d) a second inlet means communicating with said reactor means positioned for admitting a secondary particulate stream axially into said reactor means; (e) a reacting zone within said reactor means and downstream of said second inlet means through which said streams flow; (f) an antiswirl-after-section means positioned in said reactor means and downstream of said reacting zone for stopping swirling motion; and (g) an outlet means in said reactor means and downstream of said antiswirl-after-section means for removing material from said reactor means.

11. The apparatus of claim 10 wherein said first inlet means is in tangential communication with said reactor means.

12. The apparatus of claim 10 wherein said first inlet means comprises a plurality of inlets.

13. The apparatus of claim 10 wherein said antiswirl-after-section means comprises a baffle means.

14. The apparatus of claim 10 wherein said antiswirl-after-section means comprises a plurality of baffles.

15. The apparatus of claim 11 wherein said first inlet means comprises a plurality of inlets and said antiswirl-after-section comprises a plurality of baffles.

16. A process for subjecting carbonaceous particulate material to

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the influence of a stream comprising a heat-supplying particulate material comprising: (a) forming a primary swirling annular stream of an entrained heat-supplying primary particulate material, said primary swirling annular stream having a central cavity; (b) introducing into said central cavity a secondary stream comprising a fresh carbonaceous particulate material having an initial chemical composition; (c) subjecting said fresh carbonaceous particulate material to the influence of said heat-supplying primary particulate material thereby causing a transformation of said fresh carbonaceous particulate material into a substance of different chemical composition than said initial chemical composition, said substance comprising a solid product, and preventing free oxygen from being introduced into said reactor; and (d) removing all material from said reactor.

17. The process of claim 16 further comprising substantially stopping the swirling motion after said transformation has been substantially completed.

18. The process of claim 16 wherein said fresh carbonaceous particulate material is coal.

19. The process of claim 18 wherein said heat-supplying primary particulate material heats said fresh carbonaceous particulate material to pyrolyze same and to produce gaseous and solid products.

20. A process for pyrolyzing agglomerative carbonaceous material comprising: (a) forming a primary swirling annular stream comprising a heat-supplying particulate material in a reaction zone determined by a confining boundary, said primary swirling annular stream having a central cavity; (b) introducing into said central cavity a secondary stream comprising a particulate agglomerative carbonaceous material; (c) heating said particulate agglomerative carbonaceous material by the transfer of heat from said heat-supplying particulate material, thereby causing a transformation of said particulate agglomerative carbonaceous material into a form which will not adhere to said confining boundary, and thereby preventing particulate

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agglomerative material from adhering to said confining boundary, said form comprising a solid product; and (d) removing all material from said reaction zone of said reactor.

21. The process of claim 20 further comprising substantially stopping the swirling motion after said transformation has been substantially completed.

22. The process of claim 20 wherein said agglomerative carbonaceous material is agglomerative coal.

23. The process of claim 22 wherein said secondary stream comprises a gas in which said particulate agglomerative coal is entrained.

24. The process of claim 23 wherein said secondary stream comprises a gas which does not enter into a deleterious reaction with said secondary stream and the products of the process.

25. The process of claim 22 wherein said primary stream comprises a gas in which said heat-supplying particulate material is entrained.

26. The process of claim 25 wherein said primary stream comprises a gas which does not enter into a deleterious reaction with said secondary stream and the products of the process.

27. The process of claim 22 wherein said secondary stream comprises a first gas in which said particulate agglomerative coal is entrained, said primary stream comprises a second gas in which said heat-supplying particulate material is entrained, said heat-supplying particulate material is a product of the process which is recycled to the reaction zone, and said first gas and said second gas being such that they do not enter into a deleterious reaction with said streams and the products of the process.

28. The process of claim 27 wherein said secondary stream is turbulent as it is introduced into said central cavity.

29. A process for heating a carbonaceous particulate material

comprising: (a) forming a primary swirling annular stream comprising an entrained heat-supplying primary particulate material, said primary swirling annular stream having a central cavity, in a reactor means comprising (i) a conduit reactor having a circular cross-section, (ii) a first inlet means communicating with said reactor means for admitting said entrained heat-supplying primary particulate stream into said reactor means, (iii) a vane means positioned in said reactor means and spaced apart from the axis of said reactor means and downstream of said first inlet means for imparting a swirling annular motion to said entrained heat-supplying primary particulate stream, (iv) a second inlet means communicating with said reactor means positioned for admitting a secondary particulate stream axially into said reactor means, (v) a reacting zone within said reactor means and downstream of said second inlet means through which said streams pass, and (vi) an outlet means in said reactor means and downstream of said reacting zone for removing material from said reactor means; (b) introducing a secondary stream comprising a fresh carbonaceous particulate material, into said second inlet means and into said central cavity; (c) subjecting said fresh carbonaceous particulate material to the influence of said heat-supplying primary particulate material in said reacting zone to cause a transformation of said fresh carbonaceous particulate material into a substance of different chemical composition, said substance comprising a solid product; and (d) removing all materials from said reactor means through said outlet means.

30. The process of claim 29 wherein said vane means comprises a plurality of vanes.

31. The process of claim 29 wherein said vane means comprises a plurality of vanes which are positioned in an annular configuration.

32. The process of claim 29 further comprising a distributing means within said first inlet means for distributing particulate materials substantially uniformly in the primary stream.

33. The process of claim 32 wherein said distributing means com-

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prises a screen.

34. The process of claim 29 further comprising an antiswirl-after-section means communicating with said reactor means and downstream of said reacting zone for stopping swirling motion.

35. The process of claim 34 wherein said antiswirl-after-section means comprises a baffle means.

36. The process of claim 34 wherein said antiswirl-after-section means comprises a plurality of baffles.

37. The process of claim 29 wherein said second inlet means terminates downstream of said vane means.

38. A process for heating a carbonaceous particulate material comprising: (a) forming a primary swirling annular stream comprising an entrained heat-supplying primary particulate material, said primary swirling annular stream having a central cavity, in a reactor means comprising (i) a conduit reactor having a circular cross-section, (ii) a first inlet means communicating with said reactor means for admitting said entrained heat-supplying primary particulate stream into said reactor means, (iii) a swirling means positioned in said reactor means for imparting a swirling annular motion to said entrained heat-supplying primary particulate stream, (iv) a second inlet means communicating with said reactor means positioned for admitting a secondary particulate stream axially into said reactor means, (v) a reacting zone within said reactor means and downstream of said second inlet means through which said streams pass, (vi) an antiswirl-after-section means positioned in said reactor means and downstream of said reacting zone for stopping swirling motion, and (vii) an outlet means in said reactor means and downstream of said reacting zone for removing material from said reactor means; (b) introducing a secondary stream comprising a fresh carbonaceous particulate material, into said second inlet means and into said central cavity; (c) subjecting said fresh carbonaceous particulate material to the influence of

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said heat-supplying primary particulate material in said reacting zone to cause a transformation of said fresh carbonaceous particulate material into a substance of different chemical composition, said substance comprising a solid product; and (d) removing all materials from said reactor means through said outlet means.

39. The process of claim 38 wherein said first inlet means is in tangential communication with said reactor means.

40. The process of claim 38 wherein said first inlet means comprises a plurality of inlets.

41. The process of claim 38 wherein said antiswirl-after-section means comprises a baffle means.

42. The process of claim 38 wherein said antiswirl-after-section means comprises a plurality of baffles.

43. The process of claim 38 wherein said first inlet means comprises a plurality of inlets and said antiswirl-after-section comprises a plurality of baffles.

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Claims supported by Supplementary Disclosure

44. The process of claims 16, 20 and 29 wherein both said primary and secondary streams are substantially free of free oxygen by the prevention of free oxygen from being mixed with said streams during the formation of, and prior to and during introduction into said central cavity of said first and secondary streams respectively.

45. The process of claims 29 and 38 wherein said primary stream is formed in the absence of free oxygen, said secondary stream is introduced into said second inlet means in the absence of free oxygen, and free oxygen is prevented from being introduced into said reactor zone.

46. The process of claim 28 wherein said particulate agglomerative material is purged with a purge gas to substantially remove oxygen from the void space of said particulate agglomerative material before said particulate agglomerative material is formed into said secondary stream.

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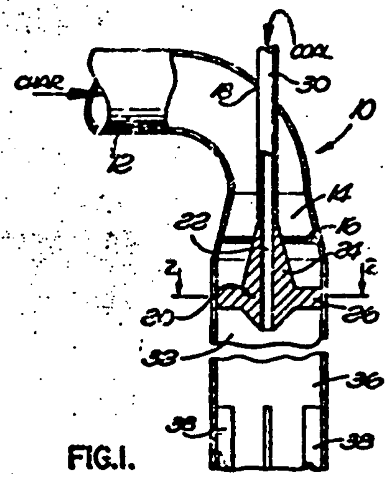

FIG.1.

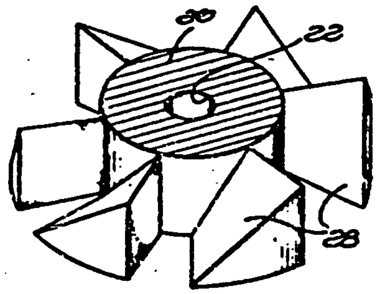

FIG.4.

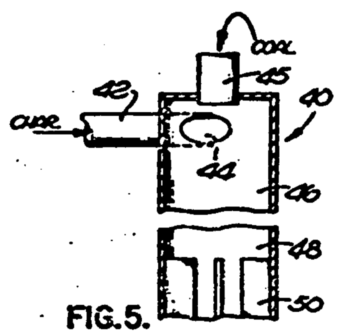

FIG.5.

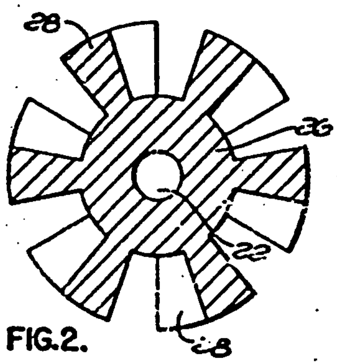

FIG.2.

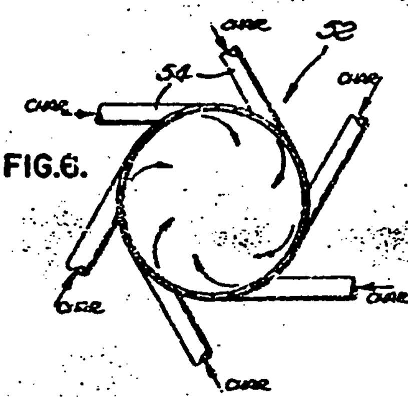

FIG.6.

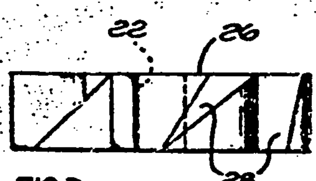

FIG.3.

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